Exhibit 2

U.S. Patent No. 7,924,802 ("'802 Patent")

Accused Instrumentalities: cellular base stations, mobile devices, and services that support 3GPP carrier aggregation, including without limitation Apple mobile devices, and all versions and variations thereof since the issuance of the asserted patent.

Claim 1

Claim 1	Public Documentation
[1pre] A method of transmitting information in a wireless communication channel comprising:	To the extent the preamble is found to be limiting, the Accused Instrumentalities perform a method of transmitting information in a wireless communication channel. For example, each Accused Instrumentality supports 3GPP carrier aggregation technologies for transmitting uplink and/or downlink information over LTE and/or NR wireless channels. Defendant's base station suppliers Nokia and Ericsson both advertise the use of carrier aggregation technologies for transmitting wireless information. User equipment devices sold by and used on Defendant's network, such as the Apple iPhone, support 3GPP carrier aggregation for transmitting wireless information. *See, e.g.*: 5.2 Downlink 5.2.1 Downlink transmission scheme A closed loop Demodulation Reference Signal (DMRS) based spatial multiplexing is supported for Physical Downlink Shared Channel (PDSCH). Up to 8 and 12 orthogonal DL DMRS ports are supported for type 1 and type 2 DMRS respectively. Up to 8 orthogonal DL DMRS ports per UE are supported for SU MIMO and up to 4 orthogonal DL DMRS ports per UE are supported for MU-MIMO. The number of SU-MIMO code words is one for 1-4 layer transmissions and two for 5-8 layer transmissions. The DMRS and corresponding PDSCH are transmitted using the same precoding matrix and the UE does not need to know the precoding matrix to demodulate the transmission. The transmitter may use different precoder matrix for different parts of the transmission bandwidth, resulting in frequency selective precoding. The UE may also assume that the same precoding matrix is used across a set of Physical Resource Blocks (PRBs) denoted Precoding Resource Block Group (PRG). Transmission durations from 2 to 14 symbols in a slot is supported. Aggregation of multiple slots with Transport Block (TB) repetition is supported. (3GPP TS 38.300 V17.4.0)

5.4 Carrier aggregation

5.4.1 Carrier aggregation

In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities:

- A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);
- A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell;
- A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG).

CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL.

(3GPP TS 38.300 V17.4.0)

6.7 Carrier Aggregation

In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below:

- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.

(3GPP TS 38.300 V17.4.0)

Claim 1	Public Documentation

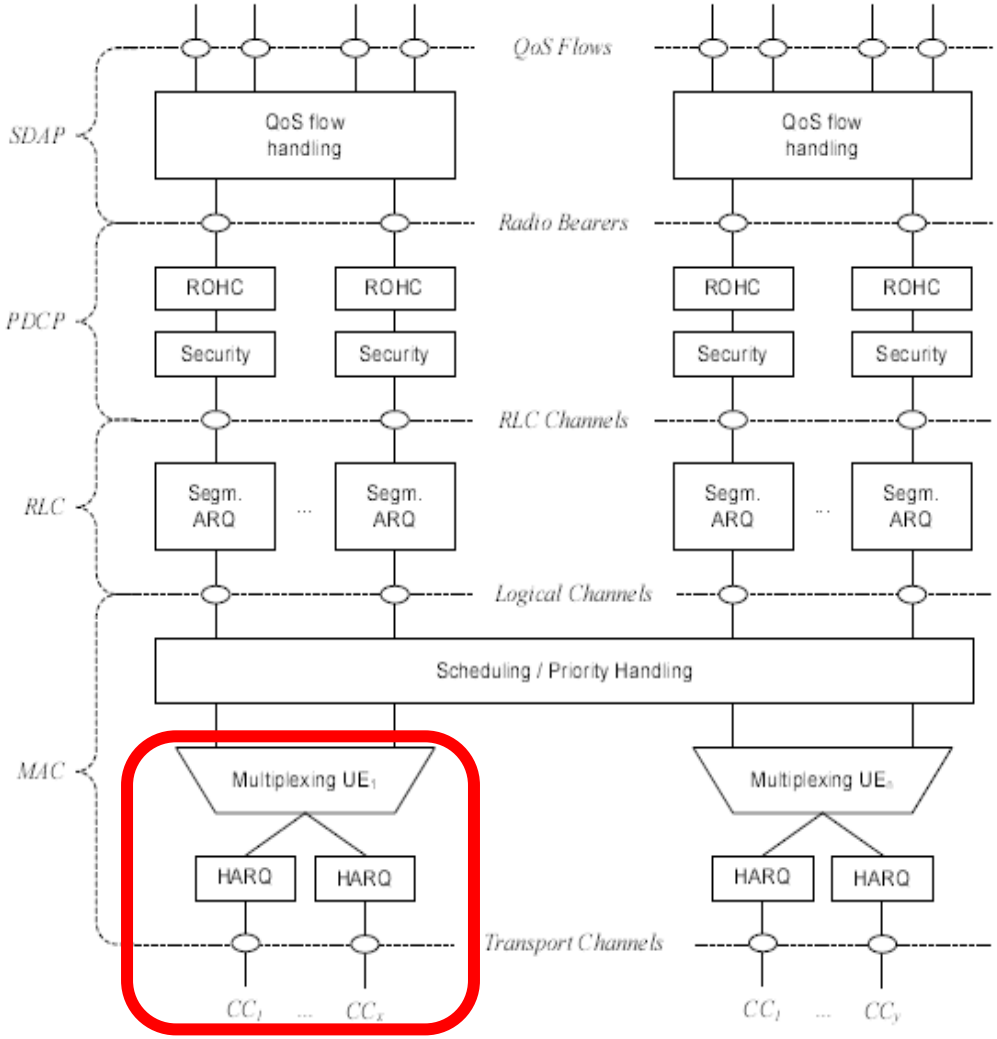
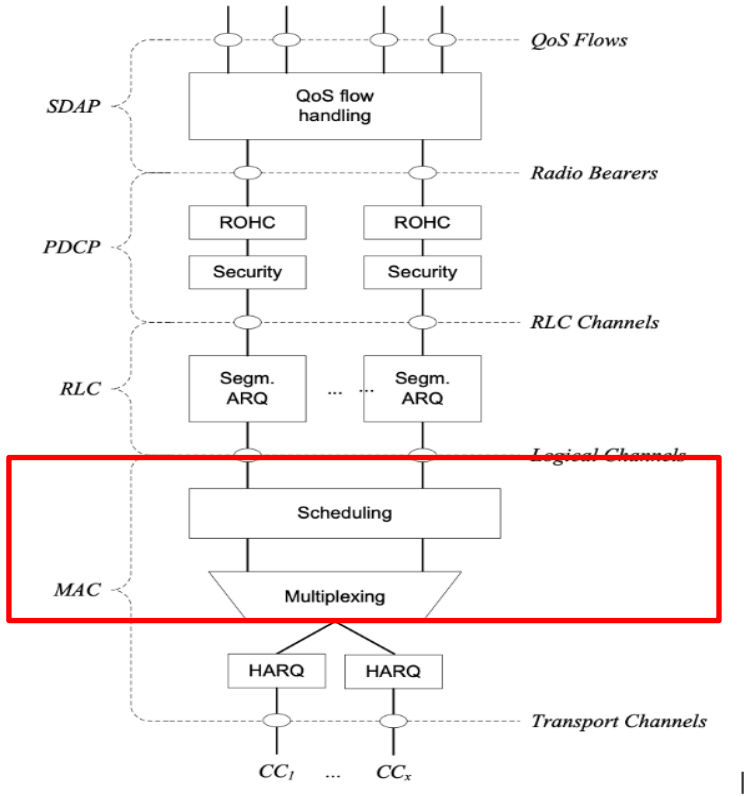


Figure 6.7-1: Layer 2 Structure for DL with CA configured

(3GPP TS 38.300 V17.4.0)

Claim 1	Public Documentation
	 **Figure 6.7-2: Layer 2 Structure for UL with CA configured** (3GPP TS 38.300 V17.4.0)

Claim 1	Public Documentation
	5G Carrier Aggregation is set to deliver a significant performance boost to mobile users but what is it and how does it work? The ongoing rollout of commercial 5G networks has significantly improved the experience for mobile subscribers around the world. As the ecosystem matures, a growing number of more advanced 5G Standalone (5G SA) networks will be central to delivering the speed and ultra-low latency to support cutting-edge applications. 5G Carrier Aggregation will play a vital role in underpinning the significant performance boost promised by 5G SA, representing an important milestone in the evolution of wireless infrastructure. Carrier Aggregation is a software functionality in Radio Access Networks and user devices which allows Mobile Network Operators (MNOs) to combine the capabilities of radio cells at distinct frequency allocations to enhance the end user experience. A key technology already in the LTE-Advanced networks, Carrier Aggregation enabled the evolution to Gigabit-LTE, achieving user data rates of more than 1 Gbps. However, in 5G networks, Carrier Aggregation will enable the evolution to multi-Gigabit-5G, reaching user data rates of about 4 Gbps and above. 5G Carrier Aggregation is also capable of improving the geographic availability, more commonly referred to as coverage, of high data rates. (https://www.nokia.com/about-us/newsroom/articles/5g-carrier-aggregation-explained/)

Claim 1	Public Documentation
	Carrier Aggregation in 5G Networks To accelerate rollout, the initial commercial 5G networks relied on the LTE infrastructure in radio access and the core network, referred to as 5G non-Standalone (5G NSA). 5G NSA allows MNOs to increase the bandwidth available to end users by bundling 4G and 5G carriers through 4G-5G Dual Connectivity. This allowed 5G users to benefit from existing LTE Carrier Aggregation capabilities with up to two 5G carriers aggregated alongside LTE carriers. To unlock the full capability of 5G, including ultra-low latency, reliability, and efficiency, MNOs are introducing 5G Standalone (5G SA) with a dedicated 5G Core and highly efficient 5G air interface, without dependency on existing LTE networks. The number of specified 5G SA Carrier Aggregation band combinations is increasing with each quarterly revision of the 3GPP specifications, enabling further options to achieve multi-Gigabit 5G data rates. These specifications are important to ensure interoperability between user equipment, such as smartphones, and networks. Between 2021 to 2022, the focus of the specifications for Carrier Aggregation in 5G SA in FR1 shifted from two component carriers to three and four component carriers. As the number of 5G frequency bands exceeds that of LTE-A, the possible Carrier Aggregation band combinations are greatly expanded, offering increased deployment options and flexibility for MNOs in different markets. (https://www.nokia.com/about-us/newsroom/articles/5g-carrier-aggregation-explained/)

Claim 1	Public Documentation
	Key benefits of 5G Carrier Aggregation Improved data speeds and throughput 5G Carrier Aggregation will boost the network performance to meet the requirements of data-hungry applications, such as augmented and virtual reality services, for both industrial and consumer use cases. Greater cell coverage As operators are looking to maximize the use of their available spectrum assets in different FDD and TDD bands, Carrier Aggregation is the key to reaching extended coverage range. This helps reduce the need to deploy new cell sites, bringing cost savings to operators. It also improves mobile user experience with consistent level of service across the network. Enhanced energy efficiency In 2019, the mobile industry made a milestone commitment to transform the sector and reach net zero carbon emissions by 2050. Carrier Aggregation has been demonstrated to reduce overall power consumption levels while increasing throughput and maintaining high service levels. This indicates that the technology could contribute to reducing overall energy usage and the mobile industry's carbon footprint. Improved coverage can also contribute to longer battery life for individual devices, requiring less frequent charging. Greater ROI According to data from GSA, the total amount raised in 2021 from spectrum auctions and assignments reached at least $140.1Bn. Radio spectrum is a finite and extremely valuable resource, representing a considerable financial burden for most MNOs. Therefore, with ever increasing demands for bandwidth, utilising this spectrum in the most efficient way becomes a top operational priority. 5G CA represents one of the most effective methods for MNOs to get the most from their outlay by maximising spectral efficiency. (https://www.nokia.com/about-us/newsroom/articles/5g-carrier-aggregation-explained/)

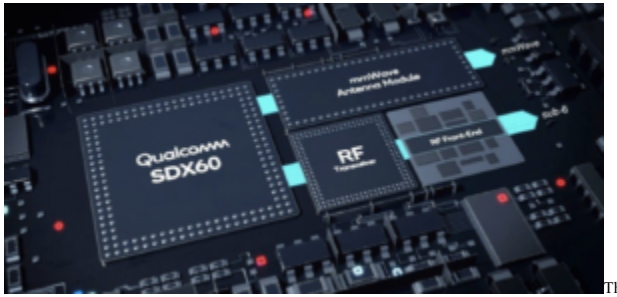
SEE WHAT CARRIER AGGREGATION CAN DO FOR YOUR NETWORK

5G Carrier Aggregation -with Coverage Boost- powered by Advanced RAN Coordination is a versatile and blended solution for high-performing 5G networks. It is a game-changer for delivering extended coverage and increased network capacity while supporting

- Higher peak rates
- Flexible band combinations
- Intra and inter RAN Compute
- Both platforms, Ericsson Radio System and Cloud RAN

(https://www.ericsson.com/en/ran/carrier-aggregation)

THE BIG FEATURE: ENHANCED 5G CARRIER AGGREGATION ON IPHONE 13



The Qualcomm X60 is the first 5G modem capable of combining different types of 5G signals together.

The additional 5G bands are actually not the biggest cellular change with the iPhone 13.

Assuming the speculation proves true and Apple is indeed using the Qualcomm X60 modem - the real key cellular feature of the iPhone 13 is support for enhanced 5G carrier aggregation.

In addition to being much more power efficient, the big jump between the X55 and X60 modems revolves around improved 5G carrier aggregation - allowing the modem to better combine multiple signals on different frequency bands.

Claim 1	Public Documentation
	To get deeper into the nitty gritty of why this is (and why we've encouraged many to consider waiting for the X60), see our featured story from June 2021: **5G Industry Update: 5G Routers, Hotspots & Antennas Are Here – But Should You Wait?** In a nutshell - the X60 is just more adept at combining long range and short range 5G signals. For example, the X60 can combine super short range mmWave with longer range mid-band or low-band 5G, helping to compensate for mmWave's range limitations. A more specific example: the X60 will allow T-Mobile's long-range low-band band n71 and super-fast mid-band n41 to be used by the modem simultaneously. This will give many T-Mobile customers the range of n71, without sacrificing the speed of n41. And another example - Verizon or AT&T will be able to combine their upcoming C-Band deployments (n77) with their longer range Sub-6 GHz 5G signals in ways that the X55 is just not capable of. (https://www.rvmobileinternet.com/apples-fall-2021-cellular-updates-new-iphone-13-modem-analysis-ipad-mini-goes-5g/#The_Big_Feature_Enhanced_5G_Carrier_Aggregation_on_iPhone_13)
[1a] transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency; and	The Accused Instrumentalities perform a method including transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency. For example, the Accused Instrumentalities transmit downlink information or uplink information on a first component carrier with a frequency range with a first center frequency (labeled $F_{C,low}$ in the excerpt from 3GPP TS 38.101 V17.9.0 below), first highest frequency (highlighted in red below), and first lowest frequency (highlighted in blue below). This applies in the cases of intra-band contiguous, intra-band non-contiguous, and inter-band CA. *See, e.g.*: 5.2 Downlink 5.2.1 Downlink transmission scheme

Claim 1	Public Documentation
	A closed loop Demodulation Reference Signal (DMRS) based spatial multiplexing is supported for Physical Downlink Shared Channel (PDSCH). Up to 8 and 12 orthogonal DL DMRS ports are supported for type 1 and type 2 DMRS respectively. Up to 8 orthogonal DL DMRS ports per UE are supported for SU MIMO and up to 4 orthogonal DL DMRS ports per UE are supported for MU-MIMO. The number of SU-MIMO code words is one for 1-4 layer transmissions and two for 5-8 layer transmissions. The DMRS and corresponding PDSCH are transmitted using the same precoding matrix and the UE does not need to know the precoding matrix to demodulate the transmission. The transmitter may use different precoder matrix for different parts of the transmission bandwidth, resulting in frequency selective precoding. The UE may also assume that the same precoding matrix is used across a set of Physical Resource Blocks (PRBs) denoted Precoding Resource Block Group (PRG). Transmission durations from 2 to 14 symbols in a slot is supported. Aggregation of multiple slots with Transport Block (TB) repetition is supported. (3GPP TS 38.300 V17.4.0) ## 5.3 Uplink ### 5.3.1 Uplink transmission scheme Two transmission schemes are supported for PUSCH: codebook based transmission and non-codebook based transmission. For codebook based transmission, the gNB provides the UE with a transmit precoding matrix indication in the DCI. The UE uses the indication to select the PUSCH transmit precoder from the codebook. For non-codebook based transmission, the UE determines its PUSCH precoder based on wideband SRI field from the DCI. A closed loop DMRS based spatial multiplexing is supported for PUSCH. For a given UE, up to 4 layer transmissions are supported. The number of code words is one. When transform precoding is used, only a single MIMO layer transmission is supported. Transmission durations from 1 to 14 symbols in a slot is supported. Aggregation of multiple slots with TB repetition is supported. (3GPP TS 38.300 V17.4.0)

5.4 Carrier aggregation

5.4.1 Carrier aggregation

In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities:

- A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);
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(3GPP TS 38.300 V17.4.0)

6.7 Carrier Aggregation

In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below:

- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.

(3GPP TS 38.300 V17.4.0)

Claim 1	Public Documentation

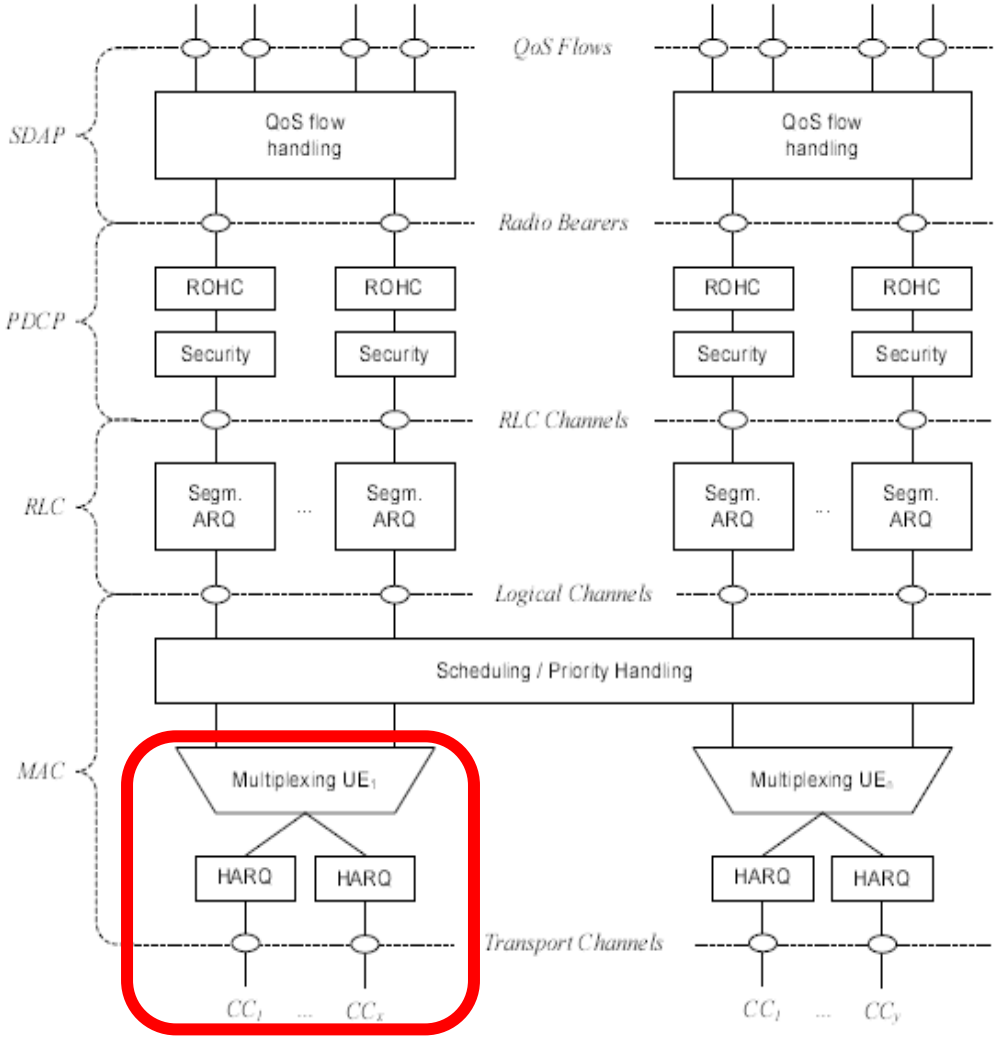
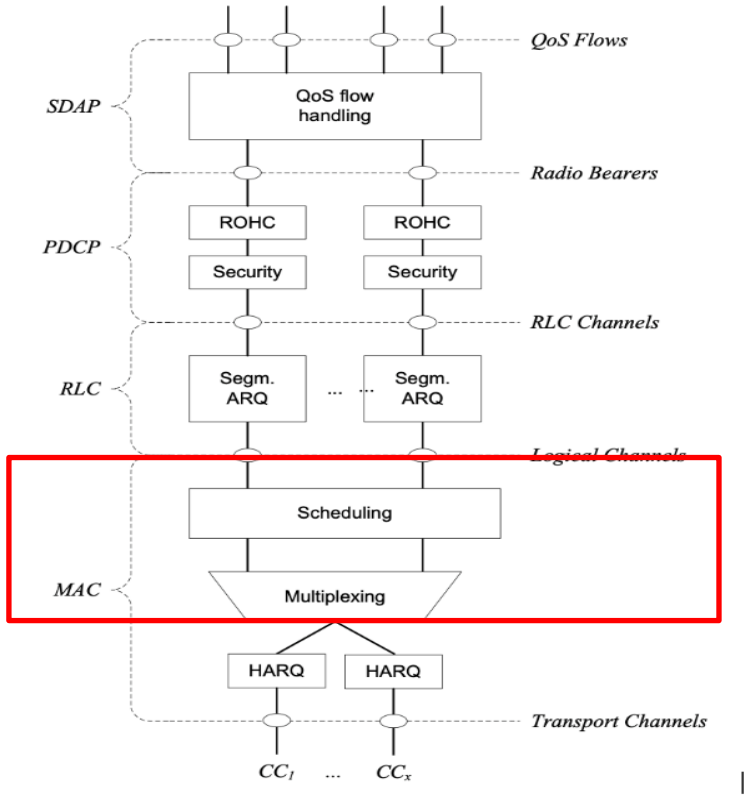


Figure 6.7-1: Layer 2 Structure for DL with CA configured

(3GPP TS 38.300 V17.4.0)

Claim 1	Public Documentation
	 **Figure 6.7-2: Layer 2 Structure for UL with CA configured** (3GPP TS 38.300 V17.4.0)

Claim 1	Public Documentation

5.3A.2 Maximum transmission bandwidth configuration for CA

For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2.

5.3A.3 Minimum guardband and transmission bandwidth configuration for CA

For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.

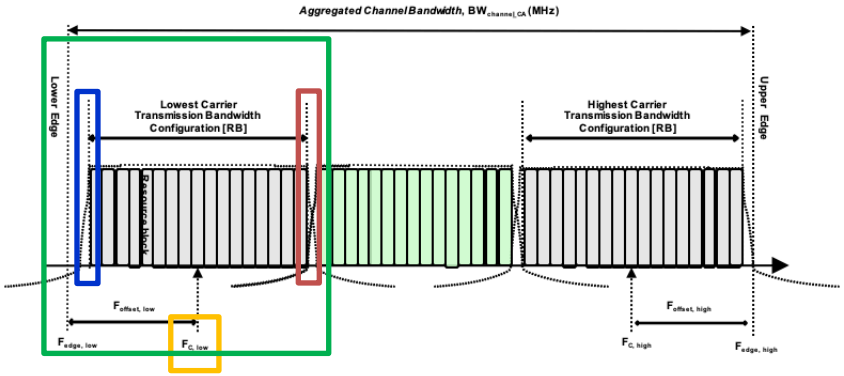


Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation

The *aggregated channel bandwidth*, $BW_{Channel_CA}$, is defined as

$$BW_{Channel_CA} = F_{edge,high} - F_{edge,low} \text{ (MHz)}.$$

The lower bandwidth edge $F_{edge,low}$ and the upper bandwidth edge $F_{edge,high}$ of the aggregated channel bandwidth are used as frequency reference points for transmitter and receiver requirements and are defined by

$$F_{edge,low} = F_{C,low} - F_{offset,low}$$

$$F_{edge,high} = F_{C,high} + F_{offset,high}$$

The lower and upper frequency offsets depend on the transmission bandwidth configurations of the lowest and highest assigned edge component carrier and are defined as

$$F_{offset,low} = (N_{RB,low} * 12 + 1) * SCS_{low}/2 + BW_{GB} \text{ (MHz)}$$

$$F_{offset,high} = (N_{RB,high} * 12 - 1) * SCS_{high}/2 + BW_{GB} \text{ (MHz)}$$

$$BW_{GB} = \max(BW_{GB,Channel(k)})$$

$N_{RB,low}$ and $N_{RB,high}$ are the transmission bandwidth configurations according to Table 5.3.2-1 for the lowest and highest assigned component carrier, SCS_{low} and SCS_{high} are the sub-carrier spacing for the lowest and highest assigned component carrier respectively. SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$ use the largest μ value among the subcarrier spacing configurations supported in the operating band for both of the channel bandwidths according to Table 5.3.5-1 and $BW_{GB,Channel(k)}$ is the minimum guard band for carrier k according to Table 5.3.3-1 for the said μ value.

In case there is no common μ value for both of the channel bandwidths, μ=1 is used for SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$ and $BW_{GB,Channel(k)}$.

Claim 1	Public Documentation

5.5A.1 Configurations for intra-band contiguous CA

Power class 3 is supported for all uplinks. Power classes other than power class 3 are supported as indicated in Table 5.5A.1-1.

Table 5.5A.1-1: NR CA configurations and bandwidth combination sets defined for intra-band contiguous CA

NR CA configuration / Bandwidth combination set								
NR CA configuration	Uplink CA configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1B	-	10	10,15				40	0
		15	15,20					
		20	20					
CA_n2B	-	5	15				20	0
		10	10					
CA_n3B	-	5	15, 20, 25, 30				60	0
		10	10, 15, 20, 25, 30					
		15, 20, 25, 30	5, 10, 15, 20, 25, 30					
CA_n5B	CA_n5B	5, 10, 15	5, 10, 15				20	0
CA_n7B	CA_n7B	10	10, 15, 20, 30, 40				50	0
		15	15, 20, 30					
		20	20, 30					
CA_n25B	-	5	15				20	0
		10	10					
CA_n38B	-	5	15, 20, 25				50	0
		10	10, 15, 20, 25					
		15, 20, 25	5, 10, 15, 20, 25					
CA_n40B	-	20	80				100	0
		50	50					
	CA_n40B	10,15, 20, 30, 40, 50, 60, 80	10, 15, 20, 30, 40, 50, 60, 80				100	1
CA_n41B	n41[3] CA_n41B	10, 20, 30, 40, 50	10, 20, 30, 40, 50				100	0
CA_n41C	n41[3,4] CA_n41C[3]	40	80, 100				180	0
		50, 60, 80	60, 80, 100					
		10	100				190	1
		15, 20	90, 100					
		40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		10	100				190	2
		15, 20	90, 100					
		30, 40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier[2]					190	4 and 5
CA_n46B	-	20, 40, 60	20, 40				100	0
CA_n46C	-	60, 80	60, 80				160	0
CA_n46D	-	60, 80	80	80			240	0
CA_n46M	-	20, 40, 60	20, 40	20, 40			140	0
CA_n46N		Void						0
	-	20, 40, 60	20, 40	20, 40	20, 40		180	1
CA_n46Q	-	20, 60	20, 40	20, 40	20, 40	20, 40	220	0
CA_n48B	CA_n48B	5	15, 20				40	0
		10, 15, 20	10, 15, 20					
		15, 20	15, 20					
	-	10	50, 60, 80, 90				100	1

(3GPP TS 38.101 V17.9.0)

Claim 1	Public Documentation

5.5A.2 Configurations for intra-band non-contiguous CA

Table 5.5A.2-1: NR CA configurations and bandwidth combination sets defined for intra-band non-contiguous CA

NR CA Configuration	Uplink CA Configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum Aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n2(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n3(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
	-	5, 10, 15, 20, 25, 30	5, 10, 15, 20, 25, 30			60	1
CA_n5(2A)	-	5, 10, 15, 20	5, 10, 15, 20			25	0
CA_n7(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n12(2A)	-	5	5			10	0
CA_n25(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
		5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40			60	1
		See n25 channel bandwidths in Table 5.3.5-1 for each carrier				60	4 and 5
CA_n25(3A)	-	5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40		55	0
		See n25 channel bandwidths in Table 5.3.5-1 for each carrier				55	4 and 5
CA_n41(2A)	n41[3,4] CA_n41(2A)	40, 50, 60, 80, 100	40, 50, 60, 80, 100			180	0
		10, 15, 20, 40, 50, 60, 80, 90, 100	10, 15, 20, 40, 50, 60, 80, 90, 100			190	1
	-	10, 15, 20, 30, 40, 50, 60, 80, 90	15, 20, 30, 40, 50, 60, 80, 90, 100			190	2
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100			190	3
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n41(3A)	n41[3,4]	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100		190	0
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n41(4A)	n41[3]	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	190	0
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n48(2A)		10, 15, 20, 40, 50, 60, 80. 90. 100	10, 15, 20, 40, 50, 60, 80. 90. 100			140[2]	0
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100			140[2]	1
CA_n48(3A)	-	10, 15, 20, 40,50, 60, 80. 90. 100	10, 15, 20, 40,50, 60, 80. 90. 100	10, 15, 20, 40,50, 60, 80. 90. 100		140[2]	0
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100		140[2]	1

(3GPP TS 38.101 V17.9.0)

Claim 1	Public Documentation
[1b] simultaneously transmitting second information across a second frequency range using the same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency.	The Accused Instrumentalities perform a method including simultaneously transmitting second information across a second frequency range using the same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency. For example, the Accused Instrumentalities transmit downlink information or uplink information on a second component carrier with a frequency range with a second center frequency (labeled $F_{C,high}$ in the excerpt from 3GPP TS 38.101 V17.9.0 below), second highest frequency (highlighted in red below), and second lowest frequency (highlighted in blue below). This applies in the cases of intra-band contiguous, intra-band non-contiguous, and inter-band CA. The transmission is performed simultaneously using the same wireless transmitter, as set out for example in section 5.4 of 3GPP TS 38.300 V17.4.0. *See, e.g.*: ## 5.2 Downlink ### 5.2.1 Downlink transmission scheme A closed loop Demodulation Reference Signal (DMRS) based spatial multiplexing is supported for Physical Downlink Shared Channel (PDSCH). Up to 8 and 12 orthogonal DL DMRS ports are supported for type 1 and type 2 DMRS respectively. Up to 8 orthogonal DL DMRS ports per UE are supported for SU MIMO and up to 4 orthogonal DL DMRS ports per UE are supported for MU-MIMO. The number of SU-MIMO code words is one for 1-4 layer transmissions and two for 5-8 layer transmissions. The DMRS and corresponding PDSCH are transmitted using the same precoding matrix and the UE does not need to know the precoding matrix to demodulate the transmission. The transmitter may use different precoder matrix for different parts of the transmission bandwidth, resulting in frequency selective precoding. The UE may also assume that the same precoding matrix is used across a set of Physical Resource Blocks (PRBs) denoted Precoding Resource Block Group (PRG). Transmission durations from 2 to 14 symbols in a slot is supported. Aggregation of multiple slots with Transport Block (TB) repetition is supported. (3GPP TS 38.300 V17.4.0) ## 5.3 Uplink ### 5.3.1 Uplink transmission scheme Two transmission schemes are supported for PUSCH: codebook based transmission and non-codebook based transmission.

Claim 1	Public Documentation
	For codebook based transmission, the gNB provides the UE with a transmit precoding matrix indication in the DCI. The UE uses the indication to select the PUSCH transmit precoder from the codebook. For non-codebook based transmission, the UE determines its PUSCH precoder based on wideband SRI field from the DCI. A closed loop DMRS based spatial multiplexing is supported for PUSCH. For a given UE, up to 4 layer transmissions are supported. The number of code words is one. When transform precoding is used, only a single MIMO layer transmission is supported. Transmission durations from 1 to 14 symbols in a slot is supported. Aggregation of multiple slots with TB repetition is supported. (3GPP TS 38.300 V17.4.0) ## 5.4 Carrier aggregation ### 5.4.1 Carrier aggregation In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities: - A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG); - A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell; - A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG). CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL. (3GPP TS 38.300 V17.4.0) ## 6.7 Carrier Aggregation In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below:

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	- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell. (3GPP TS 38.300 V17.4.0)

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5.3A.2 Maximum transmission bandwidth configuration for CA

For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2.

5.3A.3 Minimum guardband and transmission bandwidth configuration for CA

For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.

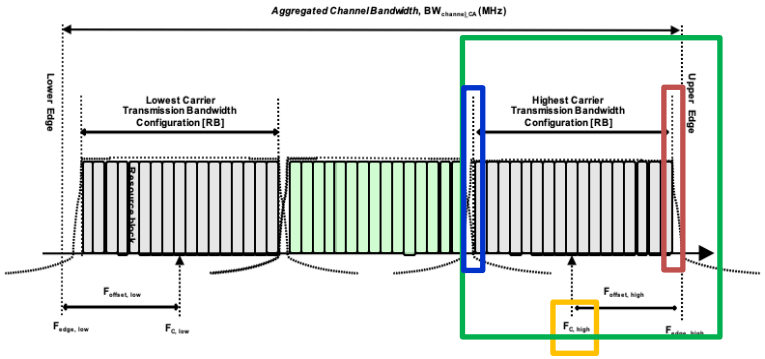

Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation

The *aggregated channel bandwidth*, $BW_{Channel_CA}$, is defined as

$$BW_{Channel_CA} = F_{edge,high} - F_{edge,low} \text{ (MHz)}.$$

The lower bandwidth edge $F_{edge,low}$ and the upper bandwidth edge $F_{edge,high}$ of the aggregated channel bandwidth are used as frequency reference points for transmitter and receiver requirements and are defined by

$$F_{edge,low} = F_{C,low} - F_{offset,low}$$

$$F_{edge,high} = F_{C,high} + F_{offset,high}$$

The lower and upper frequency offsets depend on the transmission bandwidth configurations of the lowest and highest assigned edge component carrier and are defined as

$$F_{offset,low} = (N_{RB,low} * 12 + 1) * SCS_{low}/2 + BW_{GB} \text{ (MHz)}$$

$$F_{offset,high} = (N_{RB,high} * 12 - 1) * SCS_{high}/2 + BW_{GB} \text{ (MHz)}$$

$$BW_{GB} = \max(BW_{GB,Channel(k)})$$

$N_{RB,low}$ and $N_{RB,high}$ are the transmission bandwidth configurations according to Table 5.3.2-1 for the lowest and highest assigned component carrier, SCS_{low} and SCS_{high} are the sub-carrier spacing for the lowest and highest assigned component carrier respectively. SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$ use the largest μ value among the subcarrier spacing configurations supported in the operating band for both of the channel bandwidths according to Table 5.3.5-1 and $BW_{GB,Channel(k)}$ is the minimum guard band for carrier k according to Table 5.3.3-1 for the said μ value.

In case there is no common μ value for both of the channel bandwidths, μ=1 is used for SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$ and $BW_{GB,Channel(k)}$.

(3GPP TS 38.101 V17.9.0)

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5.5A.1 Configurations for intra-band contiguous CA

Power class 3 is supported for all uplinks. Power classes other than power class 3 are supported as indicated in Table 5.5A.1-1.

Table 5.5A.1-1: NR CA configurations and bandwidth combination sets defined for intra-band contiguous CA

NR CA configuration / Bandwidth combination set								
NR CA configuration	Uplink CA configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1B	-	10	10,15				40	0
		15	15,20					
		20	20					
CA_n2B	-	5	15				20	0
		10	10					
CA_n3B	-	5	15, 20, 25, 30				60	0
		10	10, 15, 20, 25, 30					
		15, 20, 25, 30	5, 10, 15, 20, 25, 30					
CA_n5B	CA_n5B	5, 10, 15	5, 10, 15				20	0
CA_n7B	CA_n7B	10	10, 15, 20, 30, 40				50	0
		15	15, 20, 30					
		20	20, 30					
CA_n25B	-	5	15				20	0
		10	10					
CA_n38B	-	5	15, 20, 25				50	0
		10	10, 15, 20, 25					
		15, 20, 25	5, 10, 15, 20, 25					
CA_n40B	-	20	80				100	0
		50	50					
	CA_n40B	10,15, 20, 30, 40, 50, 60, 80	10, 15, 20, 30, 40, 50, 60, 80				100	1
CA_n41B	n41[3] CA_n41B	10, 20, 30, 40, 50	10, 20, 30, 40, 50				100	0
CA_n41C	n41[3,4] CA_n41C[3]	40	80, 100				180	0
		50, 60, 80	60, 80, 100					
		10	100				190	1
		15, 20	90, 100					
		40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		10	100				190	2
		15, 20	90, 100					
		30, 40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier[2]					190	4 and 5
CA_n46B	-	20, 40, 60	20, 40				100	0
CA_n46C	-	60, 80	60, 80				160	0
CA_n46D	-	60, 80	80	80			240	0
CA_n46M	-	20, 40, 60	20, 40	20, 40			140	0
CA_n46N		Void						0
	-	20, 40, 60	20, 40	20, 40	20, 40		180	1
CA_n46O	-	20, 60	20, 40	20, 40	20, 40	20, 40	220	0
CA_n48B	CA_n48B	5	15, 20				40	0
		10, 15, 20	10, 15, 20					
		15, 20	15, 20					
	-	10	50, 60, 80, 90				100	1

(3GPP TS 38.101 V17.9.0)

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5.5A.2 Configurations for intra-band non-contiguous CA

Table 5.5A.2-1: NR CA configurations and bandwidth combination sets defined for intra-band non-contiguous CA

NR CA Configuration	Uplink CA Configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum Aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n2(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n3(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
	-	5, 10, 15, 20, 25, 30	5, 10, 15, 20, 25, 30			60	1
CA_n5(2A)	-	5, 10, 15, 20	5, 10, 15, 20			25	0
CA_n7(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n12(2A)	-	5	5			10	0
CA_n25(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
		5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40			60	1
		See n25 channel bandwidths in Table 5.3.5-1 for each carrier				60	4 and 5
CA_n25(3A)	-	5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40		55	0
		See n25 channel bandwidths in Table 5.3.5-1 for each carrier				55	4 and 5
CA_n41(2A)	n41[3,4] CA_n41(2A)	40, 50, 60, 80, 100	40, 50, 60, 80, 100			180	0
		10, 15, 20, 40, 50, 60, 80, 90, 100	10, 15, 20, 40, 50, 60, 80, 90, 100			190	1
	-	10, 15, 20, 30, 40, 50, 60, 80, 90	15, 20, 30, 40, 50, 60, 80, 90, 100			190	2
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100			190	3
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n41(3A)	n41[3,4]	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100		190	0
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n41(4A)	n41[3]	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	190	0
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n48(2A)		10, 15, 20, 40, 50, 60, 80. 90. 100	10, 15, 20, 40, 50, 60, 80. 90. 100			140[2]	0
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100			140[2]	1
CA_n48(3A)	-	10, 15, 20, 40,50, 60, 80. 90. 100	10, 15, 20, 40,50, 60, 80. 90. 100	10, 15, 20, 40,50, 60, 80. 90. 100		140[2]	0
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100		140[2]	1

(3GPP TS 38.101 V17.9.0)

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	## 5.4 Carrier aggregation ### 5.4.1 Carrier aggregation In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities: - A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG); - A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell; - A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG). CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL. (3GPP TS 38.300 V17.4.0)